

GAPS & GAPS2: examples of usage

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From Science Gateways to Papers – Palermo, May 23-26 2022

GAPS Global Architecture of Planetary Systems Italian collaboration among ~8o scientists in the exoplanets field

Long-term multi-purpose observing program started in 2012 with HARPS-N at TNG, now GIARPS at TNG

Main Objectives:

- Characterization of the architectural properties of planetary systems
- Understanding the origin of planetary system diversity



GAPS

GAPS Science cases

M stars

 Frequency of Neptunes and Super Earths in the Habitable Zone of M dwarfs

Known Planets

- Search for additional low mass bodies around stars hosting known planets/planetary systems
- Characterization of known systems

Metal Poor stars

• Frequency of planets in low metallicity stars

Open Clusters stars

• Frequency of close-in planets in crowded environments

Rossiter-McLaughlin

 Characterization of the orbital alignment for known planetary systems

Star-Planet Interaction/ Asteroseismology

- Tidal interaction and its impact on the stellar activity
- Refinement of Stellar parameters

- About 350 targets, 36/40 nights/semester
- Need of dedicated management and data sharing in addition to the TNG archive





Twiki: data sharing page

2014-05-12

- * Time series tables are updated with data produced with the new version of HARPS-N pipeline. See Readme4.txt_to obtain information on the files.
- * Please note that for the F-type stars you will find values obtained both with standard masks (G2, K5, M2) and tau Boo mask.
- * Here you can find an IDL string (nothing but a simple command) that allows you to read the time_series.dat files, with short description of the header: read_dat.txt

2014-03-07

- * QUICK LOOK OF DATA REDUCED WITH NEW DRS AVAILABLE HERE: 20140307_report_new_pipeline.txt
- * Here you can find an IDL string that allow you to read the report, with short description of the header: read_report.txt

CLICK ON THE LINKS BELOW TO SEE TIME SERIES TABLES AND FILES:



GAPS KP Targets

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GAPS Name	a	ŏ	μα	μδ	Mv	<u>(B-V)</u>	Spectral Type	Radial Velocity	Number of Data	Discarded Data	Time Series	Pdf Report	Status	Update On
KP1	03:48:00.370	+40:31:50.30	0.054000	0.021100	7.24	0.634	G2	-10.100	93	0	KP1.dat	KP1.pdf	rejected	2017-10-05 at 03:50
KP2	05:23:21.570	-02:16:39.40	0.034400	-0.096900	8.94	0.761	G5	29.590	51	0	KP2.dat	KP2.pdf	rejected	2017-10-05 at 04:50
KP3	08:53:50.810	+33:03:24.50	-0.095400	-0.028400	8.03	0.626	G0	21.300	120	0	KP3.dat	KP3.pdf	active	2022-05-12 at 21:01
KP4	10:18:21.290	+12:37:16.00	-0.272300	-0.039900	7.03	0.594	G0	22.600	63	0	KP4.dat	KP4.pdf	rejected	2017-05-21 at 21:18
KP5	12:15:06.570	-07:15:26.40	-0.249700	-0.052300	7.96	0.815	G5	20.660	47	0	KP5.dat	KP5.pdf	rejected	2017-06-23 at 21:14
KP6	02:34:11.046	-12:23:03.47	0.057300	-0.187700	9.85	0.000	F2	24.250	27	0	KP6.dat	KP6.pdf	rejected	2013-01-30 at 20:38
KP7	12:30:26.900	+22:52:47.30	0.127100	-0.089400	8.76	0.738	G9	-29.600	97	0	KP7.dat	KP7.pdf	rejected	2017-02-06 at 06:06
KP8	00:15:50.850	+01:12:00.75	0.002600	0.012500	11.30	0.476	F8	18.280	12	0	KP8.dat KP8_F.dat	KP8.pdf KP8_F.pdf	rejected	2016-10-07 at 02:53
KP9	00:18:24.700	-15:16:02.30	0.025500	-0.026500	11.30	0.576	G0	8.460	12	0	KP9.dat	KP9.pdf	rejected	2016-10-07 at 00:36
KP10	00:20:40.080	+31:59:23.79	-0.004800	-0.005600	11.79	0.538	F7	-13.500	13	0	KP10.dat KP10_F.dat	KP10.pdf KP10_F.pdf	rejected	2016-07-25 at 03:03
KP11	00:38:17.560	+42:27:47.08	-0.020300	-0.005600	10.81	0.542	F8	-16.830	21	0	KP11.dat KP11_F.dat	KP11.pdf KP11_F.pdf	rejected	2017-09-15 at 03:41
KP12	02:12:31.494	+51:46:43.57	-0.010700	0.004900	11.83	0.553	G0	-21.650	35	0	KP12.dat	KP12.pdf	active	2021-08-07 at 04:55
KP13	02:49:44.488	+71:45:11.63	0.091100	-0.033100	8.17	0.000	G0	-3.300	26	0	KP13.dat	KP13.pdf	rejected	2016-10-22 at 01:11
KP14	02:54:45.140	-10:53:53.00	0.004100	0.007500	11.60	0.742	G9	25.400	12	0	KP14.dat	KP14.pdf	rejected	2016-01-03 at 20:13
KP15	03:09:28.550	+30:40:24.90	-0.004000	-0.049100	11.89	0.989	К3	4.910	24	0	KP15.dat	KP15.pdf	active	2021-09-09 at 04:49

GAPS

GAPS KP Targets

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KP15	03:09:28.550	+30:40:24.90	-0.004000	-0.049100	11.89	0.925	КЗ	4.910	24	0	KP15.dat	KP15.pdf	active	2021-09-09 at 04:49

GAPS

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2 2454174.0948104 2454177.3080400 =9. 8.215420429588 62 0.0004922713	989595093475 0.404014019679 48 900.000	0.029634413630	Ball 0.574600	Nall	13245 173.8 27.345809	43.249281231373 H11416
3 2454178.7453411 2454179.3915900 -#. #.24633133291 62 0.000499300	994490803173 0.284089499376 37 900.000	8.623379639381 1.62175	NaN 0.112400	NaN	24043 258.4 27.882927	42.434739252654 251815
4 2454179.5870606 2454180.2413500 -5. 8.259844290344 62 0.000731350	994532348667 0.544963782539 48 900.000	8,620970214501 1,41026	NaN 0.092500	NaN	4270 134.4 27.258294	42.148914314956 QNS756
5 2654182.7548718 26554848.001 -8.0008.0010-0000000 -8. 8.293566036995 02 0.000542704	989627733179 0.428628060501 05 600.000	8.622829918271 1.03048	Nall 0.514300	548 000000	19512 178.4 26.592181	42.054895380505
6 2614198.7547241 2614198.7512200 -8. 8.199599492425 62 0.000419919	969662976128 0.560560642079 100 900.000	0.041804815184 1.09409	NaN 0.415200	500000 NaN	8763 Bull 23.433658	43.809828564545 817871
7 3454199.4343747 2454199.4334400 -9. 8.190904333194 42 0.0005385738	968069748915 0.447064538040 04 600.000	8.041013425378 1.05356	Ball Ball 0.451500	Sall	12813 Bull 23.435783	43-802864875838 1353224
8 24542100.7132308 245200.710300 - 8. 8.200373534973 42 0.0004454854	967648531295 0.377495809496 170 900.000	0.041635758460 1.03405	NaN 0.514000	500000 Nall	17992 Bull 23-003354	43.728756994345 1295504
0.1010 NBA-4004-985-052- NAPH.1012-012-01204-05-1 9 2434201.4614128 2454201.4654300 -8, 8.2004351291154 62 0.0004424544 0.000 NBA-808-986-80-982- NAPH.2012-10-01293-44-0	8,256 963221619921 0,373764592834 25 960,000 10,917	8,040094474847 1,02944	NaN 0.541800	848 000000	14347 Malk 22.441553	43.793346889543 (58)98

GAPS KP Targets

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GAPS Name	a	<u>0</u>	μα	μο	MV	<u>(B-V)</u>	Spectral Type	Radial Velocity	Number of Data	Discarded Data	Time Series	Pdf Report	Status	Update On
KP1	03:48:00.370	+40:31:50.30	0.054000	0.021100	7.24	0.634	G2	-10.100	93	0	KP1.dat	KP1.pdf	rejected	2017-10-05 at 03:50
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KP12	02:12:31.494	+51:46:43.57	-0.010700	0.004900	11.83	0.553	G0	-21.650	35	0	KP12.dat	KP12.j df	active	2021-08-07 at 04:55
KP13	02:49:44.488	+71:45:11.63	0.091100	-0.033100	8.17	0.000	G0	-3.300	26	0	KP13.dat	KP13.pdf	rejected	2016-10-22 at 01:11
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KP15	03:09:28.550	+30:40:24.90	-0.004000	-0.049100	11.89	0.92g	КЗ	4.910	24	0	KP15.dat	KP15.pdf	active	2021-09-09 at 04:49

# GAPE HARE: EP1										
# ALPHA: 03:48:00.370										
# DELTA: +40:31:50.30										
# PROPER MOTION (ALPER);	0.014000									
# PROPER NOTION (DELTA).	0.021100									
# MADEITUDE: 7.36										
# (B-V): 0-616										
# SPRCTRAL TYPE: 62										
# SPECTRAL TYPE OF THE R.	AND 12									
# STREET, BUY	(km/a)									
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1										
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1 2414175,7183450	Tel.	-9,998001141209	0.361372638569	0.024518339960		Ball	Ball		14846	42.020273136257
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-0.507 NEA-MCA-INCHET	RARPH.2012-09-0970	0-00-44.547								
2 2414176.6948106	2414177,3480400	-9,989595093475	0.404014019679	0.029634413630		Rell	Raff		13245	43.244081231373
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0.146 MEA-MCA-MME-MET-	BARPH. 2012-09-04704	-34-34.395								
3 3456178,7853611	3456179.3919900	-9.994490803173	0.284089499378	0.023379039383		Nati	Kali		24043	42.034739052094
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-0.772 NEA-MGA-MWE-MET	BARPH.2012-09-0870	5-44-11-471								
4 3456179.5870606	3454100.3413500	-9,994532148647	0.544563782539	8.020970214501		Na ^N	Nati		4270	42.148914314954
0.205004250344	62 0.0007	31350048	\$90,000	1.41026	Mall	0.813500000000		136.4	27.2582942	45754
0.457 NSA-NGA-INE-RET-	BARPS, 2012-08-09701	-56-09.298								
5 3454182,7548718	3454183.4044600	-5,589827732179	0.424024040503	8.022029910273		Ball .	Na ^N		10512	42.054895380585
8.293504036995	62 0.0005	41704405	600.000	1,03049	THE	0.5141000000000		178.4	24.5921813	1313466
0.292 REA-MGA-INT-	BARPH, 2012-09-12704	-81-37.926								
6 2414198,7547243	2454198.7551200	-9,969662976128	0.540540443079	0.041804815184		Ball	Ball		8763	43.809828544545
8.199199492435	62 0.0004	41991800	900.000	1,09409	TAT	0.615200000000		Test.	22,4104188	17871
0.149 NEA-HOR-INT-RC-HET	BARPH.2012-09-2870	1-18-08.902								
7 2414199,4343747	2414199,4334400	-9,968069748915	0.467064538040	0.041013429370		Refl	Refl		12813	43.802844875838
8.190904333194	62 0.0005	28573804	600.000	1,05394	No.	0.011000000000		Ref.	23.4357400	13224
0.049 NEA-NGA-NWE-WC-	BARPH, 2012-09-29705	07-12-684								
8 3454200.7132308	3454200.7104300	-9.967648531795	0.371493809494	0.041435758440		Nati	Nati		17992	43.728756894345
8.200372558973	62 0.0004	45485470	900.000	1.00405	Na ¹	0.514000000000		No.	23.0032581	95504
0.010 NEA-HOR-SWE-HC-HET	BARPH.2012-09-3099	4-55-16.256								
9 3414201.4414124	3414203.4414300	-8.963021619921	0.373764563834	8.040094474047		No.W	No.		14347	43.743346889543
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0.000 NEA-HOR-SWE-HC-HET	BARPH.2012-10-0170	3-44-00.917								





Figure 1: Radial Velocities plot of the target star. In the upper panel the radial velocities are scaled by subtracting the mean radial velocity (see Table 2). The lower panel shows the representations



GAPS

Figure & Generalized Londo-Scorgle periodsgram as function of times (dops). The most promi-nent peak is located at 0.39 days. Histonial red lines provide an estimated value of the significance.



Miscellanea

- Modification of a copy of the GAPS fits with uniform information (target name, target RV, mask, ...)
- Matching among targets belonging to different subprograms
- Release of a default reduction with F spectral type mask (created by GAPS)



GAPS Data reduction

Principle of the HARPS-N Data Reduction Software (DRS)

ß

0.8

₀.7 CCF

-10

Stellar spectrum vs numerical mask



Credit:

https://nexsci.caltech.edu/workshop/2018/ presentations/20180724-SaganWorkshopRV-SharonXuesongWang.pdf Weighted and scaled average of the lines contained in the correlation mask: a proxy for common line profile changes (e.g. Pepe et al. 2002 and the references therein)

0

RV (km/s)

10

20

GAPS Data reduction

Different programs/targets = different needs

- Test with different masks

Find

no m

- Enlarging the CCF computation width (e.g. fast rotators)
- RV computation for «red» orders
- logR'_{HK} activity index procedure

I: in: show all	test	run Options for 2 -	make ccf
tion to auto-filter?	Tags:	targetRV	-99999
ng tools		widthccf	20
	start	stepccf	0.25
	1 - select target	C3 min order	0
	accepts: (*.hrfj) (*.hefj)	flux corr	1
	outputs: .nnj	Reduce also	False ~
	2 - make ccf	fiber B	
	accepts: C.hocj		
	outputs:		

GAPS Data reduction

Ä

Wavelength λ

YABI: Not only a basic usage for GAPS





GAPS2 & Young Objects Search and characterization of planets around young stars (< 800 Myr)

- Blind search
- Confirmation of planets found with other RV surveys
- Transiting candidate follow-up (TESS, Kepler/K2)



Large exploitation of the previous experience



GAPS2 & Young Objects

Time series pages updated for GAPS2 programs Useful to manage the observations

GAPS YO Targets

GAPS Name	ā	₫	μα	μō	Mv	<u>(B-V)</u>	Spectral Type	Radial Velocity	Number of Data	Discarded Data	Time Series	Pdf Report	Status	Update On
Y001	04:33:10.033	+24:33:43.38	-0.008000	-0.028000	12.08	0.000	M0	18.200	148	0	YO01.dat	YO01.pdf	active	2020-03-15 at 21:34
<u>Y002</u>	04:18:51.701	+17:23:16.57	0.002400	-0.016400	12.42	0.000	К7	17.000	45	0	YO02.dat	YO02.pdf	active	2021-03-24 at 20:29
Y003	04:13:14.142	+28:19:10.84	0.008800	0.005200	13.67	0.000	M4	6.800	0	0			rejected	
Y004	04:32:14.569	+18:20:14.74	0.008400	-0.015700	12.18	0.000	K7	14.600	0	0			rejected	
Y005	04:55:36.956	+30:17:55.31	0.002800	-0.019800	11.12	0.000	К0	14.100	0	0			rejected	
Y006	04:58:39.74	+20:46:44.1	0.008000	-0.025000	11.86	0.000	K7	19.043	0	0			rejected	
Y007	00:38:06.0944	+79:03:20.631	0.025100	-0.003400	11.34	0.000	K1	-8.750	45	0	YO07.dat	YO07.pdf	active	2020-11-03 at 01:23
Y008	00:39:40.1955	+79:05:30.765	0.232000	-0.002800	9.57	0.000	G0	-99999.000	0	0			rejected	
Y009	23:51:10.151	+78:58:05.00	0.026400	0.004000	11.24	0.000	К1	-8.110	38	0	YO09.dat	YO09.pdf	active	2020-01-17 at 20:10
YO10	02:17:24.734	+28:44:30.33	0.080150	-0.078400	7.74	0.000	G2	3.900	0	0			rejected	
YO11	02:27:29.254	+30:58:24.61	0.079780	-0.070000	10.12	0.000	K7	6.700	0	0			rejected	
YO12	05:20:31.832	+06:16:11.48	0.012400	-0.038800	11.68	0.000	K3	21.100	0	0			rejected	
<u>Y013</u>	04:07:01.226	+15:20:06.11	0.126000	-0.020700	10.47	0.000	К5	40.000	18	0	YO13.dat	YO13.pdf	active	2018-03-31 at 20:22



GAPS2/YO Target selection

toi-catalog

Atlas Signal Page Size:



Table wide search

Parameter Source Pipeline	Detection Pipeline(s)	TIC	Full TOI	TOI Disposition	TIC Right Ascension	TIC Declination	TIC Right Ascension 2015.5	TIC Declination 2015.5	TMag Value	TMag Uncertainty	Epoch Value	Epoch Uncertainty	Orbital Period Value	Orbital P Uncertai
qlp-s49- ff	QLP	53498154	5624.01	PC	180.845	49.2512	180.844	49.2512	10.0330	0.00600000	2641.47	0.00286510	13.7287	0.002554
qlp-s49- ff	QLP	137020480	5625.01	PC	197.143	42.3407	197.143	42.3408	9.11900	0.00700000	2661.06	0.00599400	3.46452	0.000074
qlp-s49- ff	QLP	376645976	5626.01	PC	198.299	31.6385	198.299	31.6384	9.80700	0.00600000	2660.04	0.000497200	8.07226	0.000007
qlp-s48- fa	QLP	235711993	5615.01	PC	252.935	80.1231	252.935	80.1230	13.0670	0.0100000	2625.07	0.00131870	11.7673	0.000024
qlp-s48- fa	QLP	154220877	5616.01	PC	184.902	48.6832	184.902	48.6833	14.6880	0.00700000	2634.54	0.00330560	2.00345	0.000468
qlp-s48- fa	QLP	9376973	5617.01	PC	166.951	38.1370	166.951	38.1369	13.0540	0.00700000	2635.77	0.00177860	3.15420	0.000011
qlp-s48- fa	QLP	56999883	5618.01	PC	173.070	44.1264	173.070	44.1264	12.9880	0.00700000	2630.76	0.00310710	3.52543	0.000021
	Param	Detect	TIC	Full TC	TOI Di	TIC Rig	TIC D	TIC Rig	TIC	TMag \	TMi	Epoch V	Epor	Orbita
« 1	2 3 4	»												

Showing 25 results out of 5724 items

GAPS2/YO Target selection Age determination/validation of the candidates: The crucial role of public archives

GAPS

- Rosat catalog for X-ray emission search
- Gaia catalog for kinematic and color
- Rotation period from TESS LC and past photometric surveys
- Reconnaissance spectra for Lithium
- RV from archives to exclude false positive scenarios
- Imaging observations from archives



An example

Validation of DS Tuc A b:

(almost) totally based on archival data

Rotation period from

ASAS data (2000-2008)





Mass upper limit from HARPS RVs (2005) and FP rejection from FEROS, HARPS and Gaia



100

Mass limit for possible substellar companion from NaCo data (2004 and 2009)

200

Separation (au)

A sort of GAPS

(Benatti et al. 2019)

400

300



Conclusions

- Fruitful experience between GAPS and IA2
- IA2 services useful for data sharing, custom/specific data reduction, management of the observations
- GAPS2/YO provides one of the best examples on how archival infromation is fundamental for top-level scientific publication





Thank you for your attention!